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Evaluating MC&A Effectiveness to Verify the Presence of Nuclear Materials

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Abstract

Traditional materials accounting is focused exclusively on the material balance area (MBA), and involves periodically closing a material balance based on accountability measurements conducted during a physical inventory. In contrast, the physical inventory for Los Alamos National Laboratory's near-real-time accounting system is established around processes and looks more like an item inventory. That is, the intent is not to measure material for accounting purposes, since materials have already been measured in the normal course of daily operations. A given unit process operates many times over the course of a material balance period. The product of a given unit process may move for processing within another unit process in the same MBA or may be transferred out of the MBA. Since few materials are unmeasured the physical inventory for a near-real-time process area looks more like an item inventory. Thus, the intent of the physical inventory is to locate the materials on the books and verify information about the materials contained in the books. Closing a materials balance for such an area is a matter of summing all the individual mass balances for the batches processed by all unit processes in the MBA. Additionally, performance parameters are established to measure the program's effectiveness. Program effectiveness for verifying the presence of nuclear material is required to be equal to or greater than a prescribed performance level, process measurements must be within established precision and accuracy values, physical inventory results meet or exceed performance requirements, and inventory differences are less than a target/goal quantity. This approach exceeds DOE established accounting and physical inventory program requirements. Hence, LANL is committed to this approach and to seeking opportunities for further improvement through integrated technologies. This paper will provide a detailed description of this evaluation process.

Introduction

A project team at Los Alamos National Laboratory is in the process of developing an evaluation process to quantitatively represent the effectiveness of near-real-time accounting. At the onset of this work there were few guidelines available. Some of our project team members were knowledgeable and experienced with vulnerability analysis methods, so we looked into the possibility of using these techniques. These techniques were not used because traditional vulnerability analysis methods focus on detection elements along the adversary's pathway in and pathway out, with minimum focus on detection systems at the target. We considered this a weakness in the traditional vulnerability analysis technique. However, our evaluation process accepts the value of the traditional vulnerability analysis approach and adds to it a focus specifically on detection at the target. Instead of thinking of physical layers or barriers that an adversary must pass through, we consider that near-real-time accounting provides protection at the target based on the operational needs and awareness on the items(s) of interest (special nuclear material). We claim that any actual or potential loss of material will cause an alarm, which will trigger a subsequent reaction (investigation) regardless of any path an adversary has chosen.

The development of the model, presented in this paper, began with identifying the components that constitute a near-real-time accounting system. We began by comparing traditional materials accounting, which is focused exclusively on the material balance area (MBA), and involves periodically closing a material balance based on accountability measurements conducted during a physical inventory to a near-real-time accounting system, which is established around process areas and looks more like an item inventory (rather than a physical inventory). In near-real-time accounting, we complete bookkeeping transactions involved in tracking nuclear materials in a timely fashion, i.e., very close to the actual time of the action.

We identified the components of a near-real-time accounting system to include:

1) Documenting, very soon after the actual time of the action, the transactions involved in handling/processing nuclear materials, and location and/or custody changes.

2) Identifying and monitoring for inactive items.

3) Taking credit for verification measurements that are performed as a normal course of operations.

4) Physical inventories that are designed as a performance test of the accounting records, not as a method of conducting accountability measurements or generating an inventory difference.

5) Inventory difference determinations based on the completion of a process batch/campaign, not as a part of the physical inventory.

Logically, the probability of detecting an attempted removal of a goal quantity of special nuclear material depends on the performance level of the alarm and response. In our approach we are using the term investigation to represent the MC&A anomaly resolution process. In order to claim a high probability of detection, the near-real-time accounting system's alarm and investigation must be functioning at a performance level higher than some bare minimum. The discussion that follows briefly describes the components and criteria that have been developed, at the time of this publication, for verifying that a goal quantity of special nuclear material is still present.

Handling/Monitoring Items

Consider what would occur if an operator is expecting material to perform a task and the material never arrives. The response would be immediate. Or if an operator went to find an item, perhaps Pu metal, only to discover it missing, or perhaps with a broken tamper-indicating device, an alarm would be raised, an investigation would be done, and the cause of the discrepancy would be determined unless the operator is the perpetrator (insider). To mitigate this case we consider both single person movements and two person custody changes. Now, consider two MBAs with similar inventories. In the first MBA, each item is moved or changes custody at least once a month, but in the second MBA, only half of the items are handled each month. It seems reasonable, and we will assume, that there is a higher probability of detecting a discrepancy in the MBA with a higher frequency of handling. The premise behind the handling/monitoring components of a near-real-time accounting system is that the higher the frequency for handling items (especially custody changes), the higher possibility for alarm if the item is missing or has been tampered with.

We formally capture the frequency of handling nuclear material in the calculation of an activity index. It is possible to calculate the activity index for each process within the MBA for forecasting material needs. However, we determined that calculating the activity index at the MBA level localizes information that materials managers can use to identify potential concerns that may require upgrades for either process controls or safeguards. This index includes actual movements or changes in custody for active items and physical checks of inactive items. The activity index is

$$I_{act} = {(H + M)}\big/{N}$$

where

1) H = Handling (actual movements or changes in custody for active items). Active items have physically changed location during some identified period of time (i.e., one month accounting period). Specifically, we determine handling by reviewing the accounting transaction history at month end and counting each movement as follows: Handling = internal MBA location changes and/or custody changes + receipts + shipments - containerization factor (all the items in a container show up on the accounting system, but we just count the container once).
2) M = Monitoring (physical checks of inactive items). Every month the transaction history is reviewed for special nuclear material items that are considered attractive based on graded safeguards criteria. Items with no movements or transactions within the same identified period of time (i.e., one month accounting period) are declared to be inactive. These items are placed on the inactive item monitoring list, and must be physically checked once a month, with this check being documented. Each of these checks counts for one "hit" in the M (monitoring) part of the formula for the activity index.
3) N = Number of items at month end inventory. As in computing H, we subtract a containerization factor so that we don't over-count the inventory.

To calculate the activity index for a building containing multiple MBAs, we add the individual (H+M) for each MBA, and divide by the total month-end inventory for the building, as in this equation.

$$I_{act(B)} = \frac{\sum(H+M)}{\sum N}$$

Finally, to get a better feel for the typical level of activity we perform a trend analysis of several months' indices for individual MBAs and the entire building.

We are fine tuning this model in a building with multiple category III and IV MBAs where the goal quantity has been determined to be over half of the building's special nuclear material holdings. At this time, the model is valid up to certain levels of activity, such as in the building we are considering. Future research using this model will focus on a wider range of possible levels of activity.

Going back to our premise that greater handling frequency implies greater probability of alarm, we establish a criterion value to determine whether the activity index is high or low, and assign high or low probability of alarm accordingly. For example, we might set the criterion value = 1, so that if the average activity index is equal to or greater than 1, then the probability of alarm is high. If the average activity index is less than 1, then the probability of alarm is low. This criterion value may change to some other number, as we learn more about what constitutes a "typical" high level of activity.

Verifying Items

Our next goal was to use results from the verification measurement program to help establish a probability of alarm. Verification measurements, designed to verify the accountability value of special nuclear materials (SNM), occur in a variety of settings. Some are conducted on TID items prior to introduction to a process; some are conducted during processes, some on non-TID items prior to an off-site shipment, and some during physical inventories.

Before considering the evaluation approach that we selected, it is worth digressing by briefly discussing the LANL approach to determining item verification by using precision and accuracy values for measurements. LANL maintains a measurement database that incorporates assays taken by different instruments and of items from different material types that are in many different matrices. That variety is one source of uncertainty in the measurement data. To help place some bounds on that uncertainty, LANL also maintains a remeasurement database. As the name implies, this data comes from duplicate measurements (remeasurements) of items. The remeasurement database is divided into two categories: precision and accuracy.[1]

Data on items that have been assayed multiple times by the same technique (e.g., neutron techniques) is collectively referred to as precision data. This accounts for differences due to factors such as time, room environment, operator procedure, instrument electronics, variation among like instruments, and other sample variability.

Data on items that have been assayed multiple times by different techniques, one of which is a superior technique (e.g., chemistry) is collectively referred to as accuracy data. Accuracy (the term "bias" is sometimes used) refers to the closeness of a measured value to "truth." We almost never know what the true value is, so in reality, accuracy refers to the closeness of an item's measured value on one instrument type to the measured value on a different, superior instrument type. In other words, accuracy is a measure of how well an instrument performs relative to a superior instrument.

The LANL MC&A program uses an equation with the precision and accuracy values (PAVs) to produce a decision rule for determining if the accountability value is verified. The PAVs are grouped according to material type, matrix, and measuring instrument, and represent average values for uncertainty. Although we have a high degree of confidence that the decision rule gives a correct decision for most materials, at this time there is not enough data to put a numerical confidence bound on the decision rule for every material type and matrix. The intent is that as LANL continues to build the remeasurement database, it will be possible to make a statistically based confidence statement that can be used as a part of this evaluation process.

Our goal with verifying items is to arrive at a verification index, similar to the activity index, that we can use to assign high or low probabilities of alarm. And even though we don't get a strict statistical confidence bound from using the PAVs, we have other evidence about the goodness of our verification measurements, which supports our goal of making a statement about the probability of alarm of attempted theft or diversion of special nuclear material.

Just as with handling items, we would like to say that a high the frequency for conducting verification measurements implies a high probability of alarm of missing material. At first glance this statement seems as reasonable as the corresponding assumption we made for handling items, but the truth is that just because measurements are being conducted frequently does not mean that they give good results. There are other factors to consider (e.g., the material matrix, the measurement technique) as were already discussed. Evaluating both the results and frequency of verification measurements provides usable data to meet the objective of determining a probability of alarm of missing material.

Results of verification measurements

Verification measurements do verify the accountability value a high proportion of time. To support this statement we analyzed data covering a two-year period, from a representative facility at LANL. The result shows that out of 1516 verification measurements, 1423 did verify the accountability value.

Using a hypothesis test based on the binomial probability distribution[2], it can be shown that this implies that a high proportion (at least .92) of all measurements would verify the accountability value, with 95% confidence.

So we feel confident that verification measurements do give good results. Based on that conclusion, we establish (next section) a verification index that will be used in a manner similar to the activity index.

Frequency of verification measurements

Using the near-real-time accounting data, we can identify the number of items receiving verification measurements. The verification index is

$$I_{ver} = {}^{V}\!\!\diagup_{N}$$

where

V = Number of verification measurements conducted

N = Number of items at month end inventory.

As with the activity index, it is important to obtain a verification index for a building. In the case where a building contains multiple MBAs, the calculation is

$$I_{ver(B)} = \frac{\sum V}{\sum N}$$

Just as with the activity index, we establish a criterion value in order to assign high or low verification indices. For purposes of an example only, if our criterion value is .75, then a verification index equal to or greater than .75 results in a high probability of alarm, and a verification index lower than .75 results in a low probability of alarm. And, as with the activity index, we can analyze the trends of the verification index over several months, for individual MBAs and for the building, in order to determine "typical" verification values.

Physical Inventory

Although we anticipate LANL's physical inventory practices in the future moving towards the practice of continuous inventory, this evaluation process reflects the Laboratory's current physical inventory practices. Currently, we conduct bimonthly physical inventories for category I special nuclear material. Special nuclear material holdings are divided into populations based generally on location, SNM category, and material activity. A random sample of items from each population is selected for verification measurements. LANL's current inventory practice is to determine a minimum sample size for each population so that a result of zero defects in the sample allows us to say, with 95% confidence, that a very high proportion (at least .97) of all items subject to physical inventory (PI) are without defect.

Note that a result of zero defects is not the same as saying all verification measurements pass the decision rule. Some items fail the PAV decision rule but are confirmed to be in agreement with the accountability value by the following investigation. These items are not defective. A defect in an item's nuclear material quantity occurs only if the verification measurement fails the PAV decision rule and the investigative process cannot explain the difference.

Inventory Differences

Inventory differences are determined for each process campaign/batch for a near-real-time accounting system, not as a function of the physical inventory. The inventory differences are accumulated for an accounting period (month) at the MBA level. We will be determining the contribution of the ID to the probability of alarm and ultimately the effectiveness of near-real-time accounting during the upcoming months.

Determining the Probability of Detection

The effectiveness of a safeguards system against an insider adversary is determined by the probability of detection (P_D). There are two components that make up detection: probability of alarm (P_A), and probability of investigation given that an alarm has occurred ($P_{I|A}$). The relationship is:

$$P_D = P_A \times P_{I/A}$$

When an alarm is identified, a formal process, including an investigation, is conducted to determine the cause for the alarm. LANL is conducting performance tests to confirm that this investigative process does get initiated. Based on resource projections, we are planning 25 performance tests. If at least 24 of 25 performance tests pass, we can claim, with 95% confidence (using the same statistical technique as described in the results of verification measurement) that a high proportion (at least .80) of all alarms lead to formal investigation.

Conclusion

We have described a MC&A practice that uses the concept of near-real-time accounting. Using the various components of near-real-time accounting as justification, we established an activity index for handling/monitoring nuclear materials, and a verification index for verification measurements. We described how one might use those indices to determine alarm probabilities, and then touched on how to arrive at a probability of detecting removal of nuclear material. Details on combining these probabilities will be discussed in a future forum.

References:

[1]LA-UR-99-4081, APPROACH TO IMPLEMENTING PRECISION AND ACCURACY GOAL POLICY, Pamela Dawson, Pacific Northwest National Laboratory, Dennis Brandt, NMT-4, Steve Croney, S-4, Jay Armstrong, S-4, Victoria Longmire, NMT-4, 40th Annual Meeting of the Institute of Nuclear Materials Management

[2]LA-UR-00-2438, DESIGNING SAFEGUARDS PERFORMANCE ANALYSIS TO DETERMINE AND VALIDATE DETECTION PROBABILITIES, Jerome Morzinski,

TSA-1, Pamela Dawson, Los Alamos National Laboratory S-4, 41st Annual Meeting of the Institute of Nuclear Materials Management